water market price does not greatly affect the optimal amount of applied water (data not shown). With the opportunity to sell the "conserved" water, however, profitability to the farmer increases with increasing water market prices.

With a water market price of $95 or $120 per acre-foot, the farmer's profits are higher after paying the $145 per acre-foot drainage costs than with free drainage but no water market. This finding has great significance for the western San Joaquin Valley, because it suggests that the water market would provide funds for rather large drainage disposal costs.

Conclusions

Water marketing opportunity provides several benefits. Our analysis suggests a water market price somewhere between $60 and $95 per acre-foot would induce a shift in irrigation technology, decreasing water application and making some water available to the urban sector. At the same time, the farmer's profits would equal or exceed those without water marketing.

Water marketing also leads to reduced nonpoint water pollution by greatly reducing the amount of deep percolation. The water percolating below the root zone serves as the transporting medium for agrichemical pollutants such as nitrates and pesticides. Water marketing allows the farmer to pay substantial rates for drainage water disposal with modest loss of income.

The benefits to fish and wildlife would vary and depend on the location. Negative effects of reduced water application could result from curtailed supplies of high-quality runoff water which supplies surface water bodies. Conversely, reduced subsurface drainage volumes potentially containing toxic elements would improve the quality of surface waters. Reduction of drainage water volumes and the farmer's ability to pay disposal costs could enhance the environment for fish and wildlife in the western San Joaquin Valley.

Legal, political, and implementation barriers must be overcome before a water marketing system consistent with this analysis can be adopted. Nevertheless, the results of this study clearly identify the advantages to both urban and agricultural water users and environmental quality. They also indicate that strong efforts to develop a water marketing system directed toward on-farm irrigation management are advisable.

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Cold-tolerant rose clovers

Daniel J. Drake ❑ Roger W. Benton ❑ Harry Carlson
Walter L. Graves

Seed collected from "native" or wild stands of rose clover withstood the cold, dry conditions of mountainous northern California in exploratory trials. They are potential new legume species for colder rangeland areas.

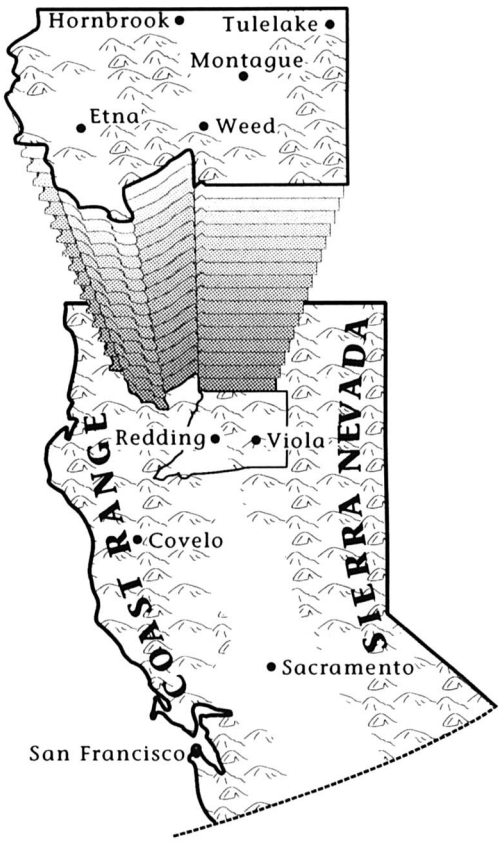
Since rose clover was introduced into California in 1944 by Merton Love, it has become an important forage species on foothill ranges. Acceptance of this winter-growing, naturally reseeding, annual clover (*Trifolium hirtum* All.) in the mild-winter climatic zones has been very good. Hard-seededness, or seed-coat impermeability, reduces water uptake by the seed, delaying germination of a portion of the seed crop for a year or more. This property allows survival during years of drought. Nitrogen-fixing by rose clover improves soil fertility. Cattle, sheep, and deer thrive on rose clover, even during the summer and fall when the plants are dry. Doves (*Columba livia* Gmelin), quail (*Lophortyx californicus* Shaw), and other birds consume and spread the seeds. It is also excellent as a low-maintenance, soil-stabilizing plant on disturbed sites.

Unfortunately, the more mountainous areas of northern California have not benefited from the use of rose clover. Over 1.7 million acres of harvested rangeland in Siskiyou, Shasta, Lassen, and Modoc counties are potentially suitable for adapted varieties of rose clover. Currently the only practical legume for these ranges is alfalfa.

Early work in Siskiyou County suggested the possibility of using rose clover. Trials in 1954 with spring (April) plantings at the H. Dillman ranch in Scott Valley and Leavers Ranch in Shasta Valley revealed approximately 3 to 4 inches of growth by May or June. No growth or long-term survival was seen, however, with a similar seeding at the Hart Ranch in Shasta Valley. In the early 1970s, similar trials with G. Barnes in Scott Valley failed to show potential.

In contrast, Wilton rose clover seeded over 25 years ago in an area east of Covelo (Mendocino County) at an elevation of 4000 feet has persisted and spread. Mt. Barker subclover was also planted in the area and performed well until the first colder than average winter. After that, the subclover was completely gone, but the rose clover remained.

"Wild" or naturalized rose clover stands have been found in both Shasta and Siskiyou counties. At 3200 and 4300 feet in eastern Shasta County, vigorously growing and blooming stands of rose clover have been seen along roadways. In Siskiyou County, at an elevation of nearly 3000 feet near the Oregon border, rose clover has been observed since 1980. Communications with previous landowners and man-



The five Siskiyou County trial locations range in elevation from 2800 to 4000 feet. Rose clover seed was collected from naturalized stands near Hornbrook, Viola, and Covelo for comparison with commercial varieties. At present, alfalfa is the only practical legume for these mountainous areas.

agers suggest initial plantings at that site in the mid-1970s.

Considering the past success, albeit limited, with annual clovers in colder locations, the lack of a practical rangeland legume for these areas, and farmer acceptance of annual clovers elsewhere in California, we conducted a series of exploratory trials. We established five trials to evaluate commercially available and naturally occurring (or wild) rose clover seed.

Rose clover selections were planted by broadcast seeding at five sites in Siskiyou County (table 1). Selections evaluated were naturally occurring rose clovers from northern California, and other clover types from northern Africa and the Mediterranean area (table 2). Commercially available varieties were used as controls.

Trial one

Twelve clover varieties were established in the fall of 1982. Naturally occurring wild rose clover seed used in the trial was collected in June 1982. Competing vegetation consisted of perennial and annual grasses with some ceanothus and starthistle. This was also the site of one of our seed collections in Siskiyou County.

Observations in the spring (1983) after the fall planting were not possible, because (1) germination of most varieties was generally poor and (2) numerous rose clover plants were found in test plots not seeded with this clover. This finding indicates spread of the naturalized rose clover. These stands have persisted through 1989.

Trial two

The second site, in Shasta Valley, was in summer fallow following grain production. The Siskiyou collection of rose clover was treated with a weak solution of hydrogen peroxide to remove rhizobia for comparisons with untreated Siskiyou seed. After

In test plots at Zwanziger Ranch near Weed (above), the California-collected rose clovers generally ranked near the top among the 21 selections tested at the site. A grain harvester (below) was used on Interstate Highway 5 near Hornbrook (with Caltrans approval) to collect rose clover seed used in exploratory trials.

TABLE 1. Description of five trials in Siskiyou County, California

Trial and location	Elevation	Soil type	Rainfall	Mean annual temperatures*	Varieties◊	Inoculant	Irrigation	Fertilizer
	feet		*inches*	*°F*				
1, Hornbrook (R Ranch)	2800	Hilt stony sandy loam & rocky outcroppings	13-18	NA,NA,50	12	No	No	No
2, Montague (York Ranch)	2900	Lassen cobbly clay	12	36,67,51	12	No	No	No
3, Tulelake (UC Field Sta.)	4000	Osborn silty clay loam (10% organic matter)	10	32,62,47	12	Yes	1st yr only	No
4, Weed (Zwanziger Ranch)	3300	Mary stony loam	29	32,66,47	21	Yes	No	P_2O_5
5, Etna (Whipple Ranch)	2800	Stoner gravelly sandy loam	18	34,67,50	1	No	1st yr only	No

NOTE: Randomized complete block design with three replications used for trials 1, 2, 3, and 4 (trial 5, one replication.) Analysis by ANOVA with separation by LSD. In trial 4, rose and sub clover varieties as groups were compared by orthogonal contrasts.
* NA data not available
◊ All varieties in all trials established by broadcast seeding.

seeding in the fall of 1982, numbers of plants per plot were counted in mid-April and mid-May 1983. Following the April data collection, 1 pound 2,4-DB was applied to control annual weeds.

An average of 17 and 12 plants per plot were found in April and May, respectively. There were variety differences (table 3). Rose clovers such as Hykon and Siskiyou were generally ranked near the top at each observation.

Vigor scores a year later again suggested rose clovers were more successful than sub clovers, and performance by naturalized Siskiyou or Mendocino clovers was as good as commercial varieties. All varieties showed very small growth, approximately 2 to 3 inches in height, or less. Considerable weed competition or perhaps poor nodulation by rhizobia (inoculant was not supplied at seeding) may have been responsible for the generally unsatisfactory growth. Cooperator management plans changed, causing removal of this test plot.

Trial three

The clover varieties were seeded, with appropriate inoculants, in November 1984 into a prepared seedbed. Selections included experimental wild collections from high elevations in the Mediterranean region and North Africa.

Management during the first year, in addition to regular irrigations, included clipping twice to control weeds (primarily volunteer barley and oats), one pesticide application (Poast 0.375 pound per acre, 1.5 Emulsifiable Concentrate on June 14, 1985), and one hand-weeding. Second-year management consisted only of one hand-weeding.

Counts of plants per plot were made in mid-June 1985, and percent ground cover was estimated in early and late June 1986.

All varieties planted at the UC Tulelake Field Station produced some plants in the first spring (table 4). There were, however, large variations in numbers, and differences were not statistically significant.

By June of the second year, differences were more striking. Ground cover estimates ranged from 55% to 0. Yuchi Arrowleaf, Shasta 4300-foot (Viola) Rose, and Mendocino Rose clovers were superior. The two subclovers in the trial, Mt. Barker and Nungarin, and Jemalong medic were unable to produce plants in the second year.

A third year of evaluation was not possible, because the more successful varieties or strains spread into adjacent plots.

The generally superior soil in Tulelake (at least compared with surrounding granitic soils), greater water holding capacity, and weed control made the conditions of this trial very favorable. However, the trial was conducted in an extremely cold environment.

TABLE 2. Varieties used in exploratory trials for cold tolerant annual clovers adapted to mountainous northern California

Selection	Scientific name	Source/location
Alfalfa, Spreador	*Medicago sativa* L.	Commercial/USA
Beenog Cupped Clover	*Trifolium cherleri* L.	Commercial/Australia
Cupped Clover #253	*T. cherleri* L.	Native/Morocco
Geraldton Subclover	*T. subterraneum* L.	Commercial/Australia
GR434 Subclover	*T. subterraneum* L.	Native/Morocco
GR435 Subclover	*T. subterraneum* L.	Native/Morocco
GR448 Subclover	*T. subterraneum* L.	Native/Morocco
GR450 Subclover	*T. subterraneum* L.	Native/Morocco
GR494 Subclover	*T. subterraneum* L.	Native/Morocco
GR508 Subclover	*T. subterraneum* L.	Native/Moroccco
GR519 Subclover	*T. subterraneum* L.	Native/Morocco
GR567 Subclover	*T. subterraneum* L.	Native/Morocco
Hykon Rose Clover	*T. hirtum* All.	Commercial/USA/Australia
Jemalong Medic	*M. truncatula* Gaert.	Commercial/USA/Australia
Kondinin Rose Clover	*T. hirtum* All.	Commercial/USA/Australia
Lisare Cupped Clover	*T. cherleri* L.	Commercial/Australia
Mendocino Rose Clover	*T. hirtum* All.	Native/California
Mt. Barker Subclover	*T. subterraneum* L.	Native/USA/Australia
Nungarin Subclover	*T. subterraneum* L.	Commercial/USA/Australia
Olympus Rose Clover	*T. hirtum* All.	Commercial/USA/Australia
SA 65321-A Cream Subclover	*T. subterraneum* L.	Native/Morocco
SA15077 Subclover	*T. subterraneum* L.	Native/Turkey
Shasta 3200' Rose Clover	*T. hirtum* All.	Native/California
Shasta 4300' (Viola) Rose Clover	*T. hirtum* All.	Native/California
Sirint Rose Clover	*T. hirtum* All.	Commercial/USA/Australia
Siskiyou Rose Clover	*T. hirtum* All.	Native/California
Siskiyou (Treated) Rose Clover	*T. hirtum* All.	Native/California
WA 65324-J Subclover	*T. subterraneum* L.	Native/Morocco
Wilton Rose Clover	*T. hirtum* All.	Commercial/USA
Woolgenellup Subclover	*T. subterraneum* L.	Commercial/USA/Australia
Yamina Cupped Clover	*T. cherleri* L.	Commercial/Australia
Yuchi Arrowleaf	*T. vesiculosum* Savi.	Commercial/USA

NOTE: Commercial varieties are generally readily available; naturalized selections are found in wild conditions. Seed from naturalized strains has been collected for testing through cooperative exchange programs with various institutions.

TABLE 3. Average plants per plot on two dates and vigor score a year later, trial two

	Average plants/plot*		Avg. vigor score* ◊
Selection	4/15/83	5/12/83	4/13/84
Yuchi Arrowleaf	0.3 c	1.0 d	2.0 a
Sirint Rose	3.7 bc	5.7 cd	1.3 ab
Mendocino Rose	37.0 a	31.7 ab	1.0 abc
Olympus Rose	3.3 bc	1.7 d	1.0 abc
Siskiyou Rose	46.7 a	24.7 bc	0.7 bc
Hykon Rose	49.7 a	47.7 a	0.3 bc
Mt. Barker Sub	31.7 a	9.7 cd	0.3 bc
Wilton Rose	5.0 bc	5.7 cd	0.3 bc
Geraldton Sub	26.0 ab	4.7 cd	0.3 bc
Woolgenellup Sub	0.7 bc	0.7 d	0.3 bc
Kondinin Rose	0.3 c	3.3 d	0.0 c
Siskiyou Treated	4.0 bc	2.3 d	0.0 c
LSD at P=.05	25.7	20.7	1.3

* Means followed by different letters within columns differ significantly (P<.05).
◊ Ratings on a scale of 0 to 3 with 3 the best.

TABLE 4. Trial three, Tulelake Field Station, average values

	Plants/plot*	Ground cover◊	
Selection	6/12/85	6/5/86	6/24/86
		%	%
Arrowleaf	14.0	11. b	55 a
Shasta 4300' (Viola) Rose	6.0	35. a	55 a
Mendocino Rose	5.8	38. a	48 a
Yamina Rose	5.0	5. bc	20 b
Lisare Rose	8.5	10. bc	18 b
Siskiyou Rose	2.3	9. bc	11 b
Mt. Barker Sub	2.0	6. bc	6 b
Wilton Rose	3.5	4. bc	6 b
Hykon Rose	11.3	10. bc	5 b
Beenog Rose	4.3	1. bc	1 b
Jemmalong Medic	7.3	0. c	0 b
Nungarin Sub	2.0	0. c	0 b

* Values not significantly different; relative variation was high; CV = 69%.
◊ Means followed by different letters within columns differ significantly (P=.05).

TABLE 5. Trial four, Zwanziger Ranch, average density (germination) as plants per plot, vigor, and flowering score on various dates

Selection	Plants per plot			Vigor score*		Flowering scores*
	3/2/87	4/2/87	5/8/87	4/17/87	5/8/87	5/8/87
Beenog Cup	1.0 cdef	1.7 bcd	1.7 bcd	1.0 e	1.3 bcd	3.0 a
Cup #253	0.3 ef	0.7 ef	1.0 d	1.0 e	0.7 de	2.0 abcd
GR434 Sub	1.7 abcde	0.7 ef	1.7 bcd	1.0 e	1.7 abc	2.0 abcd
GR435 Sub	1.3 bcdef	1.0 de	1.3 cd	1.7 cd	1.3 bcd	1.7 abcd
GR448 Sub	1.7 abcde	1.3 cde	1.0 d	1.3 de	1.3 bcd	1.3 bcde
GR450 Sub	0.7 def	1.3 cde	1.3 cd	2.0 bc	1.3 bcd	0.7 de
GR494 Sub	1.0 cdef	1.7 bcd	1.7 bcd	2.3 b	2.3 a	1.0 cde
GR508 Sub	2.7 ab	1.0 de	1.0 d	1.0 e	1.3 bcd	0.0 e
GR519 Sub	2.0 abcd	1.0 de	2.0 abc	1.0 e	1.7 abc	0.0 e
GR567 Sub	1.3 bcdef	1.3 cde	1.3 cd	1.0 e	1.0 cd	0.0 e
Hykon Rose	2.3 abc	2.0 abc	1.7 bcd	1.3 de	2.0 ab	2.7 ab
Mendocino Rose	3.0 a	2.7 a	2.7 a	1.0 e	2.0 ab	1.7 abcd
SA 65321-A Cream Sub	2.0 abcd	1.3 cde	1.7 bcd	1.3 de	1.0 cd	0.7 de
SA15077 Sub	1.7 abcde	1.3 cde	1.0 d	1.3 de	1.0 cd	0.0 e
Shasta 3200' Rose	2.7 ab	2.3 ab	2.3 ab	2.0 bc	2.3 a	2.0 abcd
Shasta 4300' Rose	1.7 abcde	1.7 bcd	2.7 a	1.3 de	2.3 a	1.7 abcd
Siskiyou Rose	1.7 abcde	2.0 abc	2.7 a	1.7 cd	2.3 a	2.0 abcd
Spreador Alfalfa	0.0 f	0.0 f	0.0 e	0.0 f	0.0 e	0.0 e
WA 65324-J Sub	1.0 cdef	1.0 de	1.7 bcd	1.7cd	1.3 bcd	1.0 cde
Yamina Cup	2.3 abc	1.3 cde	1.7 bcd	1.0 e	1.7 abc	2.3 abc
Yuchi Arrowleaf	2.0 abcd	2.7 a	2.7 a	3.0 a	2.3 a	0.0 e
LSD at alpha=.05	1.6	1.0	1.0	.6	.9	1.4

NOTES: Means followed by different letters within columns differ significantly. Rose and sub clover varieties as groups were compared by orthogonal contrasts.
* Scores for vigor and flowering are on a scale of 0 to 3, lowest value to highest. Flowering score 0 was used for no flowers. Plots with at least 1 flower were scored as 1.

Trial four

The fourth site, near Weed, was in a pine transition zone. In this trial, preplant treatment consisted of broadcast application of 7.7 pounds of single superphosphate over the experimental area (40 by 84 feet) at a rate of 20 pounds P_2O_5 per acre.

The 21 clover varieties were seeded in early September 1986 into 4- by 4-foot plots at a rate of 60 pounds per acre with inoculant (pelgel-pelinoc). A ring roller was used once to lightly firm the seedbed.

In the spring of 1987, two people assigned scores based on visual assessments. Germination or density was scored on March 2, April 2 and 27, and May 8; vigor, based on plant height and abundance of leaves, on April 2 and May 8; and flowering on April 17 and May 8.

There were variety differences in germination as early as March and also in the April and May observations. Rose clovers had higher germination scores (averaging 2.3) than subclovers (averaging 1.5) in March (table 5). This pattern remained in April and May. The California-collected rose clover usually ranked near the top in each evaluation for germination. By May, the four highest ranking rose clovers were the California collections, with Hykon the next ranked rose clover at position ten.

Early in the growing season, the varieties showed differences in vigor. But unlike the germination results, vigor scores of rose and subclovers were similar (averaging scores of 1.5 and 1.4, respectively). Most of the varieties did not show good growth by April 17. Between April 17 and May 8, rose clovers showed dramatic increases in vigor compared with subclovers (averaging 2.2 vs. 1.4). The varieties ranking high in germination were also high in vigor, including Mendocino, Siskiyou, Shasta 4300 and 3200 rose clovers, Yuchi Arrowleaf clover, and GR519 subclover.

The early flowering varieties were the Cup clovers and Hykon rose clover, which had flowers by April 17. By May 8, variety differences were more striking with 15 varieties having flowers and 6 without flowers. More rose clovers than subclovers had flowers (average scores of 2.0 vs. 0.8). Along with most of the subclovers, alfalfa and Yuchi Arrowleaf clover were also without flowers on May 8. The naturalized California rose clover varieties again had high scores.

Trial four began at the start of a 2-year drought. Observations for signs of germination in the plots in the second year were made near the end of March and again in April 1988. The only varieties that produced plants that year were Siskiyou, Shasta 4300 and 3200, and Mendocino rose clover. Poor growth was not unexpected in the second year of a substantial drought. Good stands of rose clover in the Sacramento Valley are practically nonexistent during extreme drought years but return during periods of more normal rainfall.

Trial five

Trial five, in Scott Valley, evaluated only naturalized Siskiyou County rose clover seeded in mid-November 1984 at 25 pounds per acre into approximately 400 square feet of unreplicated test plot. Management consisted of periodic sprinkler irrigation, along with occasional clipping to control weeds in the first year. Observations for persistence have been made yearly.

Germination and growth have occurred during each of the four years since establishment. Observations suggest numbers of plants and vigor have varied between years.

Conclusions

Our trial results suggest rose clover seed collected from four locations in northern California—Siskiyou, Shasta at 3200 feet, Shasta 4300 feet (Viola), and Mendocino—has a better ability than commercial varieties do to withstand cold, dry conditions. Limited testing of rose clover and other varieties or strains collected for cold tolerance from other parts of the world also suggests the California naturalized strains are superior.

Rose clovers tested were more persistent than subclovers, being more likely to germinate and grow for at least a 2-year period.

Our exploratory trials were often limited to 2 years. It would have been valuable to have continued them, but the shortening of trials was frequently due to the success of specific varieties rather than failure. As varieties successfully reseeded, their encroachment on other varieties made further data collection impossible. Observations of trial sites in subsequent years confirm persistence of naturalized selections.

These findings confirm observations of the long-term persistence of naturalized clover stands from which the California seed was collected. The Mendocino site has persisted for over 20 years. Interviews suggest the Siskiyou site has been expanding for at least 10 years. And at least 4 years have elapsed since the first sighting of the Shasta County stands. This information, considered with the experimental data, provides strong evidence for adapted rose clover varieties that are superior to current commercial varieties.

Because of the extent of the potential reseeding sites and the scarcity of alternative legumes for these locations, seed increase and release of naturalized cold tolerant rose clovers are being undertaken.

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